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Completion pneumonectomy for chronic mycobacterial disease

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Objective: Patients with persistent pulmonary infections from mycobacterial disease present a difficult clinical challenge. These individuals typically have poor pulmonary function, malnutrition, and other comorbidities, and few guidelines exist regarding optimal therapy. We report our experience with completion pneumonectomy as part of a multidisciplinary treatment program for patients with recurrent, persistent mycobacterial disease.

Methods: During a 9-year period, 26 consecutive patients underwent completion pneumonectomy for mycobacterial disease. All patients underwent intensive, guided preoperative antibiotic therapy and aggressive nutritional supplementation. Complete surgical resection of the remaining destroyed or infected lung tissue was performed, often through an extrapleural dissection with intrapericardial ligation of vessels. Vascularized tissue flaps were used whenever possible to buttress the bronchial stump closure. Postoperative management consisted of a multidisciplinary approach, with ongoing antibiotic and nutritional therapy.

Results: The primary organisms were *Mycobacterium avium* complex (n = 15), *Mycobacterium tuberculosis* (n = 5), *Mycobacterium abscessus* (n = 3), *Mycobacterium xenopi* (n = 2), and *Mycobacterium chelonae* (n = 1). Operative mortality was 23% (6/26): respiratory failure or adult respiratory distress syndrome in 2 cases, sepsis in 2, bronchopleural fistula in 1, and pulmonary embolism in 1. Significant morbidity occurred in 46% (12/26). Among the 17 long-term survivors, sputum conversion or discontinuation of medications was achieved in 14 (82%). Mean length of follow-up was 45 months (range 4-105 months).

Conclusion: Completion pneumonectomy remains an important component of therapy in patients with mycobacterial disease who have had failure of previous therapy. Although associated with significant risks, successful outcomes can be achieved with an organized, multidisciplinary approach and careful postoperative follow-up.

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Pulmonary mycobacterial disease is a complex problem that is primarily treated with medical therapy. However, some patients require surgical therapy for chronic, persistent disease. Indications for surgical intervention include failure to thrive, persistent localized cavitary disease or destroyed lung, persistent sputum positivity, hemoptysis, bronchopleural fistula (BPF), and bronchial stenosis.

Completion pneumonectomy is performed on a subgroup of these patients who have undergone a previous pulmonary resection for a mycobacterial disease–related process or for other underlying lung disease. Indications for completion pneumonectomy are similar to those for primary resectional therapy. We report our experience with 26 patients undergoing completion pneumonectomy for chronic mycobacterial disease.

TABLE 1. Comorbidities in patients undergoing completion pneumonectomy

Condition	No.	%
Anemia	20	77
Smoking history (>15 pack-years)	15	58
Obstructive pulmonary disease	9	35
Restrictive pulmonary disease	10	34
Steroid use	4	15
Asthma	3	12
Restrictive and obstructive pulmonary disease	2	8
Coronary artery disease	1	4
Diabetes	0	0

TABLE 2. Indications for undergoing completion pneumonectomy

Condition	No.	%
Destroyed lung	24	92
Cavitary disease	22	85
Constitutional symptoms (fevers, weight loss)	21	81
Persistent positive sputum	17	65
Hemoptysis	9	35
BPF	5	19
Antibiotic intolerance	2	8
Bronchial stenosis	1	4

Patients and Methods

We reviewed the hospital charts of 26 consecutive patients who underwent completion pneumonectomy for chronic mycobacterial infection at the University of Colorado Hospital between September 1994 and September 2003. The study was approved by the University of Colorado Hospital's institutional review board. Completion pneumonectomy was defined as any procedure in which any remaining lung was removed after a previous partial resection. All patients were operated on by a single surgeon. There were 19 female patients and 7 male patients. The average age was 55 years (range 21-73 years). Fifteen patients underwent right completion pneumonectomy, and 11 patients underwent left completion pneumonectomy.

Previous operations included right upper lobectomy in 10 patients, right lower lobectomy in 1, right middle lobectomy in 1, left upper lobectomy in 9, left lower lobectomy in 1, segmental or wedge resection in 3, and bullectomy in 1. The indications for the previous operation were resection for complications of mycobacterial disease in 15 patients, bronchiectasis-related pathology in 6, bleb or bullous disease in 4, and complications of Wegener granulomatosis in 1. For the patients who had bronchiectatic disease as an indication, it was unknown whether they had mycobacterial infection at the time of initial resection because of the difficulty of isolating and culturing mycobacteria in vitro. Twenty-two patients had one previous operation, 3 patients had two previous operations, and 1 patient had three previous operations. Two of the patients also had previous thoracoplasty. Only 2 of the 26 patients had the initial operation performed at the University of Colorado Hospital. The interval between previous operation and completion pneumonectomy was 3 months to 46 years, with a mean interval of 12.7 years.

Infecting organisms were *Mycobacterium avium* complex in 15 patients, multidrug-resistant *Mycobacterium tuberculosis* in 4, nonresistant *M tuberculosis* in 1, *Mycobacterium xenopi* in 2, *Mycobacterium chelonae* in 1, *Mycobacterium abscessus* in 1, and both *M chelonae* and *M abscessus* in 2. Eleven of the patients had polymicrobial infection, with *Aspergillus* species in 8, *Pseudomonas* species in 2, and *Klebsiella* species in 1. Sixty-five percent of the patients had sputum positive for mycobacteria at the time of operation.

Significant comorbidities were present in 85% of the patients and are summarized in Table 1. Many patients had bronchiectasis, either primary or secondary to the chronic mycobacterial disease. The average serum albumin level at the time of operation was 3.1 ± 0.66 g/dL (range 2.2-4.7 g/dL). Seventy-seven percent of the patients were below ideal body weight, and 50% of these patients were more than 10% below ideal body weight. These values represent body mass after 2 to 3 months of aggressive nutritional supplementation. The average hemoglobin level was 11.1 ± 2.2 g/dL (range 8.0-18.2 g/dL), with most patients having a diagnosis of anemia of chronic disease.

Indications for operation are listed in Table 2. Almost all the patients had persistent fevers, weight loss, and general failure to thrive. Lung destruction or cavitary disease was present in all cases, with chronic obstructive or restrictive pulmonary disease a common underlying problem. In 5 cases, the presence of a BPF was the primary indication for completion pneumonectomy. Chronic hemoptysis was present in several patients; however, it was the primary indication for operation in only 1 case. No patients had massive hemoptysis. Treatment consisted of a multidisciplinary approach, with involvement of thoracic surgeons, infectious disease specialists, pulmonologists, a nutritionist, and a physical therapist. Weekly multidisciplinary conferences were used to plan and reevaluate ongoing therapy. Patients underwent chest radiography, computed tomography, pulmonary function testing, split function perfusion testing, and bronchoscopy.

Patients received at least 2 to 3 months of preoperative antimicrobial therapy in an attempt to convert sputum to a negative status or to decrease the bacterial count in the sputum. All patients were treated with aggressive, individualized antibiotic therapy on the basis of in vitro drug susceptibility testing; however, none of the 18 patients with positive sputum had conversion to a negative status. The mycobacterial count usually reached a nadir after 3 months of therapy, and surgical intervention was then performed. Sputum specimens were collected bronchoscopically to ensure adequate sampling and decrease the likelihood of contamination. Antimicrobial therapy was continued, typically for 2 years postoperatively, on the basis of the status of serial sputum collections.

At the time of initial evaluation, a complete nutritional assessment was made, and aggressive nutritional supplementation commenced. One of the patients in this group received a preoperative feeding gastrostomy, and another received a nasojejunal tube. All patients who had poor preoperative oral intake were strongly encouraged to have feeding tubes placed at the time of surgery; however, only 3 consented to have this performed. With close

dietician monitoring, patients received nutritional supplements during the preoperative antibiotic course. Our experience with these patients has been that few actually gained weight as a result of their chronic catabolic state. Despite good caloric intake under the supervision of a dietician, little weight gain was observed. This finding may, however, have been related to lack of adequate feedings in these patients.

Preparation for surgery also involved evaluation with chest radiography, contrast-enhanced computed tomography, bronchoscopy, pulmonary function testing, and ventilation and perfusion scintigraphy. Echocardiography was also performed, and right heart catheterization was performed if there was evidence of pulmonary hypertension. Patients were selected for completion pneumonectomy according to the requirement of a postoperative forced expiratory volume in 1 second (FEV_1) greater than 800 mL. The mean preoperative FEV_1 was 1.54 ± 0.43 L (0.88-2.84 L), and the mean perfusion values of the operated side were 15.8% (range 0%-30%) for left-sided resections and 17.8% (range 0%-36%) for right-sided resections. The average postoperative predicted FEV_1 values were 1.39 L (range 0.82-2.2 L) for left-sided resections and 1.25 L (range 0.60-2.1 L) for right-sided resections.

Anesthetic and Analgesic Considerations

Surgical resection was performed with the patient under general anesthesia with a double-lumen endobronchial tube or a standard endotracheal tube with a bronchial blocker. Endobronchial separation is critical to prevent pooling of purulent secretions into the dependent healthy lung during the operation. Bronchoscopy was performed to clear the airways of any mobile secretions. Epidural catheters were placed in all patients. Ketorolac tromethamine (INN ketorolac) was also administered and was given postoperatively for as long as 72 hours. We have found orally administered low-dose benzodiazepines to be helpful in reducing the degree of postoperative pain and the need for narcotics in these patients.

Surgical Technique

All mycobacterial antibiotics were administered the morning of surgery, and intravenous cefazolin was administered before skin incision. A posterolateral thoracotomy was performed on all patients, usually following the line of the previous incision scar. In many cases, the latissimus dorsi muscle (LDM) had been at least partially divided at the previous operation. We made every attempt to salvage this muscle because of the excellent mediastinal coverage it provides. The LDM was detached from its insertion on the chest wall. The serratus anterior was spared. The fifth or sixth rib was then resected as far medially as possible, which not only facilitated exposure but also helped to define the extrapleural plane. The intercostal muscle pedicle was carefully preserved for later use as a buttress for the bronchial stump. In several cases, no muscle was available for coverage, and omentum therefore was harvested through an upper midline abdominal incision. The omentum was carefully divided, with care to avoid injury to the gastroepiploic vessels, with the blood supply based on the right gastroepiploic artery. The omentum was tagged with a heavy silk and then brought up toward the pleural space at the junction of the anterior chest wall and the diaphragm. After the lung was resected, the anterior diaphragm was traversed and the omentum was retrieved.

Once the thoracic cavity was entered, adhesions were carefully taken down. In 20 patients, the inflammatory process had eroded into the chest wall, and partial dissection of the chest wall was performed in a deep extrapleural plane. In the apex of the pleural space, one must take care to avoid injury to the subclavian vessels, especially given the poor visibility in this area. If lung tissue is densely adherent, it is better to leave some lung parenchyma behind than to risk vessel injury. Dissection along the mediastinum was performed, identifying the pulmonary artery and vein. In cases where a previous left or right upper lobectomy had been performed, the inferior vein was isolated and divided extrapericardially. The remaining left superior or right superior vein was then isolated and divided intrapericardially, which in turn facilitated intrapericardial identification, isolation, and division of the pulmonary artery. If intrapericardial dissection was not possible because of excessive adhesions, the bronchus was controlled and divided first, and then the vessels were controlled with this improved exposure. The right pulmonary artery was usually controlled by dissection under the superior vena cava or between the aorta and the superior vena cava. If a previous lower lobectomy had been performed, then extrapericardial dissection and isolation of the vessels was usually possible. Vessels were divided with a vascular stapling device. In patients with a contaminated pleural cavity for whom an Eloesser procedure was planned, if dense inflammatory tissue was present on the mediastinum, this tissue was left to be débrided with dressing changes. The argon beam coagulator was routinely used to control the diffuse bleeding from the chest wall after the dissection was completed.

Management of the Bronchial Stump

The bronchus was closed with a TA-30 4.8-mm stapler (United States Surgical Corporation, Auto Suture Company Division, Norwalk, Conn) in all but 1 case. In that single patient, the right lateral trachea was torn during the dissection and was repaired and closed with interrupted 3-0 Prolene suture (Ethicon, Inc, Somerville, NJ). The bronchial stump was reinforced with LDM in 14 of the patients (54%), with intercostal muscle in 3 (12%), and with omentum in the remaining 9 (35%). The LDM was brought into the chest cavity through a defect in the chest wall created by resection of the third or fourth rib and then sutured around the bronchus and mediastinal structures with absorbable suture. Similarly, the intercostal muscle or omentum was tacked down around the bronchus and mediastinal structures. We always interposed muscle between the pulmonary artery and the bronchial stump.

Management of the Pleural Space

Patients who had frank purulent material or heavy contamination in the pleural space underwent an Eloesser procedure during the same operative session. This was performed by resecting two to three ribs at the medial aspect of the thoracotomy. All the skin was preserved, and the epithelialized tract was fashioned by turning down the upper portion of the flap with interrupted sutures of 2-0 nylon fiber. The ribs laterally and remaining soft tissues were then approximated. The cavity was packed with dilute povidone-iodine–soaked Kerlix gauze (The Kendall Company, Mansfield, Mass).

After the bronchial stump reinforcement was completed, 2 L of cefazolin-containing solution was used to irrigate the pleural cavity, and a Pulsevac was used if there was heavy soilage. No

thoracostomy tubes were placed during chest closure; however, 600 to 700 mL of air was aspirated from the pleural space once the skin was closed.

Intraoperative blood loss was carefully recorded and replaced 1:1 with packed red blood cells and colloid in the form of 5% albumin or fresh-frozen plasma. This practice appears to decrease the crystalloid requirement and also the amount of third-spacing postoperatively. No autotransfusion devices were used, because we believe that autotransfusion may promote bacteremia and sepsis syndrome.

After completion of the procedure, thorough toilet bronchoscopy was performed, because it is common for secretions from the diseased lung to pool into the dependent remaining lung. The patient was then extubated in the operating room and transported to the surgical intensive care unit, where careful postoperative monitoring was performed for 24 to 48 hours. All patients were given supplemental oxygen therapy to maintain a pulse oximeter oxygen saturation of 90% to 92%. Intravenous cefazolin was continued for 24 hours, and all mycobacterial medications are continued throughout the hospital course. Aggressive pulmonary toilet was performed; this included incentive spirometry and Acapella valve (DHD Healthcare, Wampsville, NY) therapy, as well as percussive chest physiotherapy three to four times daily. Respiratory therapists dedicated to the thoracic service served these patients in the intensive care unit and on the thoracic surgery ward. Patients were fluid restricted to 1500 mL/d, and diuretic therapy was administered to maintain a negative fluid balance. Patients were out of bed for several hours during the day, and ambulation was started on postoperative day 1 with the aid of physical and occupational therapists. Aggressive nutritional support was continued postoperatively with oral supplements and, if necessary, nasoduodenal feeding tubes.

Patients with Eloesser flaps had the dressing removed on postoperative day 2, and subsequent dressing changes were performed every 2 days with half-strength Dakin solution–soaked Kerlix gauze. After discharge, these patients then returned to the University of Colorado Hospital for closure of the Eloesser, which was performed after 4 to 6 weeks, depending on the degree of contamination and the presence of granulation tissue. We débrided any tissue that appeared to be infected or covered with eschar. The edges of the thoracostoma were débrided to healthy bleeding tissue, and the soft tissue planes were dissected. From 500 to 1000 mL of Clagett solution was placed into the pleural cavity, and the skin edges were approximated in a watertight fashion with a deep layer of absorbable suture followed by interrupted cutaneous nylon sutures, which were left in place for 3 to 4 weeks. Patients could be then be discharged the same day or within 24 hours of surgery. Patients were continued on their mycobacterial medication regimens for as long as 2 years, with periodic sputum sampling.

Results

Operative Details

Operative time ranged from 114 minutes to 400 minutes, with a mean operative time of 253 ± 82 minutes. The mean estimated blood loss during the procedure was 1090 ± 832 mL (range 350-4000 mL). Perioperative blood transfusions averaged 3.77 units per patient (range 0-14 units), and the overall blood transfusion rate was 92%. Reexploration for persistent postoperative bleeding did not occur. Intraoperative complications included a laceration of the left atrium in 1 patient, a tear in the pulmonary artery in 1 patient, and a tracheal injury in 2 patients; both tracheal injuries were repaired primarily. One patient underwent a splenectomy after spleen injury during taking down of the omentum. Most patients had extrapleural dissections with heavy inflammatory involvement of the apex of the lung.

TABLE 3. Postoperative morbidity after completion pneumonectomy

Complication	No.	%
Bronchopleural fistula	7	27
Respiratory failure	5	19
Pneumonia	5	19
Arrhythmia	3	12
Adult respiratory distress syndrome	2	8
Deep vein thrombosis	2	8
Wound complication	2	8
Myocardial infarction	1	4
Empyema without bronchopleural fistula	0	0
Postoperative bleeding necessitating thoracotomy	0	0

Mortality

There were no intraoperative deaths. There were 6 postoperative deaths during the initial hospitalization, 4 of which occurred within 30 days of the operation, (mortality 23%). Two patients, 1 of whom had preexisting pulmonary hypertension, died of adult respiratory distress syndrome. Other causes of in-hospital mortality included BPF with subsequent pneumonia and multisystem organ failure, pulmonary embolus, *Aspergillus* species sepsis with multisystem organ failure, and sepsis-related complications.

There were two late (<90 days) outpatient deaths. One was that of a patient who, after treatment for a BPF, was discharged to a nursing home in another state and died 2 weeks later of unknown causes. Another was that of a patient discharged home after an uneventful postoperative course who died of unknown causes 2 months later.

Morbidity

Complications after completion pneumonectomy were encountered in 12 patients (46%), and the incidences of these complications are summarized in Table 3. Respiratory failure was defined as ventilator dependence longer than 24 postoperative hours, need for reintubation, or need for noninvasive positive-pressure ventilation. One patient had an uncomplicated myocardial infarction. The patients who had atrial arrhythmias develop were rate controlled and had no hemodynamic instability. There were 2 seromas that formed

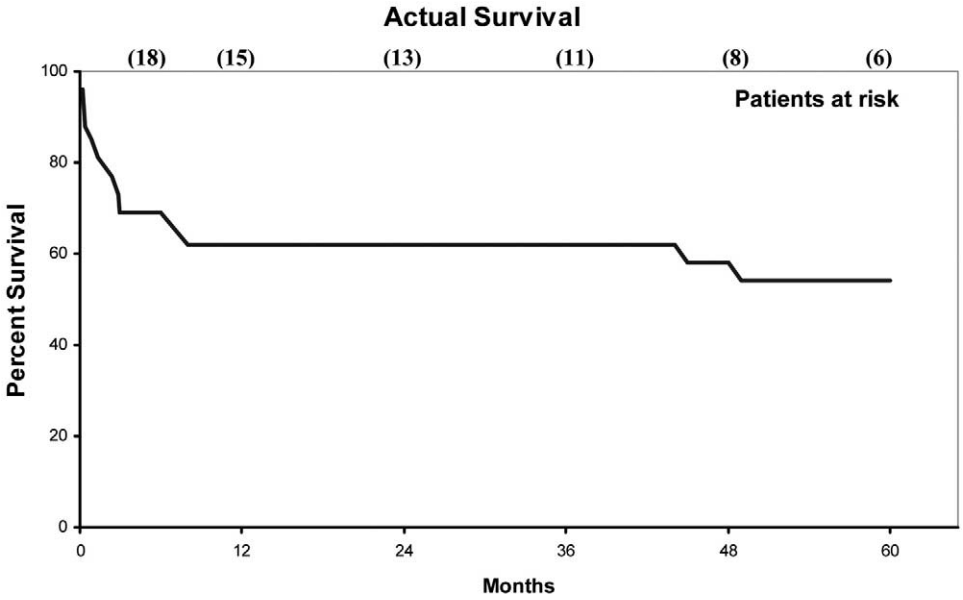

Figure 1. Actual survival of patients undergoing completion pneumonectomy.

at the LDM harvest site after the drain was removed. These required no intervention and resolved spontaneously. There were no empyemas independent of a BPF. Two patients had subclavian vein thrombosis develop at the site of a peripherally inserted central catheter; 1 of them died of a pulmonary embolus.

BPFs developed in a total of 7 patients, 4 early (<30 days) and 3 late (range 2-17 months). Three of the 4 patients in the early group died, and there were no deaths in the late group. Of the 7 patients, 5 had positive sputum at the time of operation. All the BPFs were on the right side, and all had stapled bronchial closure with LDM flap coverage. Two of the early BPFs occurred in patients who had been intubated for pneumonia. The other 2 occurred in patients with polymicrobial infections, 1 of whom had a postoperative predicted FEV_1 of 0.6 L and severe malnutrition with an albumin of 2.2 g/dL. Among the patients with late BPFs, 1 patient was receiving long-term steroid therapy, 1 was chronically malnourished, and the other had a relatively uncomplicated postoperative course except for uncomplicated pneumonia.

Early BPFs were initially managed with a chest tube. Five patients underwent either transmediastinal closure with a sternohyoid muscle flap or transthoracic closure with a revised LDM flap. An Eloesser thoracostoma was performed at the same time, and a Clagett procedure was performed 4 to 6 weeks later for the patients who survived. One patient underwent transbronchial bioglue closure, which eventually broke down; this patient died in a nursing home on postoperative day 86. The patient who did not have a fistula closure performed had early multisystem organ failure develop, and support was withdrawn.

Five patients underwent Eloesser procedures at the time of the initial surgery; 4 of them had a BPF as an indication for completion pneumonectomy. Three of these patients were long-term survivors and returned 4 to 6 weeks after discharge for a Clagett procedure. Among the patients who survived past hospital discharge, the median stay was 7.5 days (range 3-99 days). The overall actual survival was 54% (Figure 1), and the 3 deaths that occurred longer than 6 months postoperatively were all consequences of respiratory failure. Of the 17 long-term survivors, 14 had conversion of sputum to negative or were able to stop taking mycobacterial antibiotics.

Discussion

Disease caused by mycobacteria can be classified into infection with *M tuberculosis* and environmental mycobacteria *(EM).* EM includes *M avium* complex, *M xenopi,* and *Mycobacterium kansasii,* as well as rapidly growing organisms such as *M abscessus, Mycobacterium fortuitum,* and *M chelonae.* The incidence of *M tuberculosis* infection had been increasing in the United States, with more than 50,000 excess cases reported during the period between 1985 and 1992.[1] During the past 10 years, these numbers have declined slowly, but in 2003 there were still a total of 14,871 *M tuberculosis* cases reported in the United States. Despite this overall decline, *M tuberculosis* continues to be a problem in certain areas of the country, where rates have increased in such populations as foreign-born persons and

racial and ethnic minorities.[2] There has been an increase in the proportion of multidrug resistant tuberculosis cases and in the number of young persons infected. The HIV epidemic has resulted in an increasing number of persons at risk for reactivation of latent tuberculosis.[3]

EM are free-living bacteria that have been recovered from surface and tap water, soil, domesticated animals, inanimate objects, and food products. Transmission to human beings is likely through inhalation or oral ingestion. These organisms most commonly cause pulmonary infection in immunocompromised patients or in those with preexisting lung disease. Another group of individuals with a high incidence of EM pulmonary infection is that of thin, middle-aged, nonsmoking white women with midlung field nodular bronchiectasis.[4,5] Because of the lack of human-to-human transmission, the epidemiology in not completely known; however, there may be as many as 3000 new *M avium* complex cases annually, and this incidence may be increasing.[6]

There is a general consensus regarding drug therapy for tuberculosis. However, there is a paucity of data regarding optimal drug treatment for EM. Drugs used to treat EM infections include clarithromycin and azithromycin, rifampin (INN rifampicin), ethambutol, aminoglycosides, fluoroquinolones, cycloserine, clofazimine, ethionamide, and isoniazid. At National Jewish Medical and Research Center in Denver, Colorado, combinations of these drugs are used according to in vitro susceptibility testing and therapeutic drug monitoring to optimize efficacy and reduce toxicity. The duration of therapy is typically 24 months, because shorter treatment periods have been associated with an increased risk of relapse.[7]

Medical therapy for mycobacterial disease has progressively improved during the last several decades. With the increasing numbers of patients with multidrug-resistant *M tuberculosis* and EM infections, however, surgical therapy is becoming more common. Because of the indolent nature of EM disease, patients undergoing surgery typically have more extensive parenchymal destruction, and this in turn promotes a spiraling deconditioned preoperative status. In this study, 77% of the patients were below their ideal body weight, and 77% also had anemia. Despite aggressive nutritional supplementation, the average preoperative albumin level was still only 3.1 g/dL. This deficiency, coupled with significant underlying lung disease, puts these patients at high risk for complications. We have considered even more aggressive nutritional supplementation with feeding tubes for all patients with malnutrition (gastrostomy tubes or nasojejunal tubes); however, many patients refuse feeding tubes or do not tolerate them.

Resectional therapy is considered when patients have localized, extensive damage to the lung parenchyma or airways, which is considered to predispose toward treatment failure.[7] Indications for surgery include cavitary disease, destroyed lung tissue, continued sputum positivity despite maximal drug therapy, chronic hemoptysis, BPF, and bronchial stenosis. Most patients have several of these characteristics. Almost all these patients have constitutional symptoms such as fevers, malaise, weight loss, and general failure to thrive. Of significant concern is the potential contamination of relatively healthy contralateral lung parenchyma. Surgical intervention should be performed before spillage of bacteria occurs with further respiratory deterioration.

Resectional therapy for TB and EM disease has been described by us and others. We have had favorable outcomes for patients undergoing primary resectional therapy, with excellent operative morbidity and mortality and high rates of sputum conversion. This has been shown in patients with middle lobe and lingular disease,[8] as well as patients with multidrug-resistant *M tuberculosis*.[9] Primary or completion pneumonectomy for any benign disease carries with it significant morbidity and mortality. Reed and colleagues[10] described their experience with pneumonectomy in 13 patients with chronic pulmonary infection, including 2 patients with mycobacterial disease. Although the perioperative mortality was only 7.6%, they reported significant morbidity, such as long operative times with large operative blood loss, as well as a BPF rate of 23%. Other groups have also reported significant morbidity, with higher rates of intraoperative bleeding, empyema, and BPF when primary pneumonectomy is performed for sequelae of tuberculosis.[11,12] Our early experience with primary pneumonectomy for mycobacterial disease also demonstrated a higher risk for BPF and mortality, particularly among patients with EM. This may be due to the more indolent nature of these infections, which leads to more profound chronic malnutrition and immune system compromise. These patients also tend to be older and have more comorbidities than patients with tuberculosis.

Completion pneumonectomy is associated with even higher morbidity and mortality, particularly when performed for benign or infectious disease. Several large series have documented mortalities as high as 27.6%, as well as higher rates of cardiopulmonary morbidity and other major complications.[13-15] Chronic inflammation and fibrosis, particularly in the hilum, make the surgical procedure technically demanding, and distorted tissue planes increase operative times. Routine intrapericardial dissection and vessel ligation probably reduce the incidence of exsanguinating hemorrhage; however, the usual requirement for an extrapleural dissection makes blood loss more significant. Although there were no deaths from exsanguinating hemorrhage, 93% of our patients required blood transfusion, potentially increasing morbidity and mortality.[13]

Bronchial stump fistula is a feared complication of pneumonectomy, and various reports in the thoracic surgery literature report incidences of 0% to 23%, with a higher occurrence when the operation is performed for benign disease.[10,16] Demonstrated risk factors for BPF include right pneumonectomy, postoperative mechanical ventilation,[17] the presence of chronic obstructive pulmonary disease, poor postoperative FEV_1, lack of bronchial stump coverage,[18] and perhaps the presence of pleuropulmonary infection.[17] In this series, we had 7 BPFs, all of which were right sided, and most affected patients had at least one of these defined risk factors. We learned in our previous experience that the use of muscle or tissue flaps to buttress the bronchial stump led to a decrease in the rate of persistent air leaks and possibly BPFs in primary lobar resection for mycobacterial disease. However, we had a BPF rate of 47% in our early experience with pneumonectomy for EM infection, despite the use of muscle coverage.[8] Other groups have reported the benefits of using autologous tissue for bronchial stump coverage in pneumonectomy for cancer and benign disease[13,18,19] which may also potentially reduce the incidence of BPF.[20] Repair of BPF with autologous tissue has been shown to be beneficial in several studies[21,22] and is routine in our practice. We avoid using the serratus anterior for any muscle flap because of the complications of shoulder girdle dysfunction and winged scapula–related problems with wound healing and skin necrosis. Because of our incidence of BPF with LDM coverage, we now try always to use omentum for bronchial stump coverage, particularly in right-sided resections. Additionally, we have recently changed our practice and instead of using a stapled bronchial closure, we now perform a tailored suture closure.

Postpneumonectomy empyema, a complication that is usually life-threatening, was not observed in any of our patients. Our aggressive use of an Eloesser flap at the time of completion pneumonectomy probably prevented this from occurring. The Eloesser is well tolerated by the patients, and an experienced nursing staff is helpful in facilitating dressing changes and educating the patients and their families. Appropriate analgesic techniques make this experience tolerable. We continue dressing changes for 4 to 6 weeks postoperatively, until the space is clean and granulating, and do not routinely use tissue culture results when deciding to close the Eloesser. Patients are generally discharged within 24 hours of surgery, and we have not seen any complications in this group of patients.

Another important aspect of the care of these patients is aggressive pulmonary toilet. Early mobilization, coughing and deep breathing exercises are facilitated by the routine use of epidural catheters (despite the infected nature of the cases, we have not seen an infected epidural catheter in any or our patients with mycobacterial infection). Nebulizer therapy with chest physiotherapy by experienced respiratory therapists and hourly incentive spirometer and Acapella valve use by the patients help to prevent secretion pooling, atelectasis, and consequent pneumonia.

Completion pneumonectomy is an important component of therapy for patients with chronic mycobacterial disease. Although associated with high morbidity and mortality, careful patient selection and a well-organized multidisciplinary approach can optimize clinical outcomes. Patients infected with EM tend to have the most problems because of the indolent nature of the disease, and many become severely debilitated. Most of these patients are unable to work, posing significant burdens for their friends, families, and society. Resectional therapy may be the only hope for many of these patients, who are essentially dying slowly of their disease.

References

1. Cantwell MF, Snider DE Jr, Cauthen GM, Onorato IM. Epidemiology of tuberculosis in the United States, 1985 through 1992. *JAMA*. 1994; 272:535-9.
2. Centers for Disease Control and Prevention. Trends in tuberculosis—United States, 1998-2003 [erratum in *MMWR Morb Mortal Wkly Rep.* 2004;53:246]. *MMWR Morb Mortal Wkly Rep.* 2004;53:209-14.
3. Selwyn PA, Hartel D, Lewis VA, Schoenbaum EE, Vermund SH, Klein RS, et al. A prospective study of the risk of tuberculosis among intravenous drug users with human immunodeficiency virus infection. *N Engl J Med*. 1989;320:545-50.
4. Aksamit TR. *Mycobacterium avium* complex pulmonary disease in patients with pre-existing lung disease. *Clin Chest Med.* 2002;23:643-53.
5. Prince DS, Peterson DD, Steiner RM, Gottlieb JE, Scott R, Israel HL, et al. Infection with *Mycobacterium avium* complex in patients without predisposing conditions. *N Engl J Med*. 1989;321:863-8.
6. O'Brien RJ, Geiter LJ, Snider DE Jr. The epidemiology of nontuberculous mycobacterial diseases in the United States. Results from a national survey. *Am Rev Respir Dis*. 1987;135:1007-14.
7. Iseman MD. Medical management of pulmonary disease caused by *Mycobacterium avium* complex. *Clin Chest Med*. 2002;23:633-41, vii.
8. Pomerantz M, Madsen L, Goble M, Iseman M. Surgical management of resistant mycobacterial tuberculosis and other mycobacterial pulmonary infections. *Ann Thorac Surg*. 1991;52:1108-12.
9. Pomerantz BJ, Cleveland JC Jr, Olson HK, Pomerantz M. Pulmonary resection for multi-drug resistant tuberculosis. *J Thorac Cardiovasc Surg*. 2001;121:448-53.
10. Reed CE. Pneumonectomy for chronic infection: fraught with danger? *Ann Thorac Surg*. 1995;59:408-11.
11. Massard G, Dabbagh A, Wihlm JM, Kessler R, Barsotti P, Roeslin N, et al. Pneumonectomy for chronic infection is a high-risk procedure. *Ann Thorac Surg*. 1996;62:1033-8.
12. Conlan AA, Kopec SE. Indications for pneumonectomy. Pneumonectomy for benign disease. *Chest Surg Clin North Am*. 1999;9:311-26.
13. Miller DL, Deschamps C, Jenkins GD, Bernard A, Allen MS, Pairolero PC. Completion pneumonectomy: factors affecting operative mortality and cardiopulmonary morbidity. *Ann Thorac Surg*. 2002;74:876-84.
14. McGovern EM, Trastek VF, Pairolero PC, Payne WS. Completion pneumonectomy: indications, complications, and results. *Ann Thorac Surg*. 1988;46:141-6.
15. Terzi A, Furlan G, Terrini A, Magnanelli G. Completion pneumonectomy: experience with 47 cases. *Thorac Cardiovasc Surg*. 1995;43:52-6.
16. Deschamps C, Bernard A, Nichols FC 3rd, Allen MS, Miller DL, Trastek VF, et al. Empyema and bronchopleural fistula after pneumonectomy: factors affecting incidence. *Ann Thorac Surg*. 2001;72:243-8.
17. Wright CD, Wain JC, Mathisen DJ, Grillo HC. Postpneumonectomy bronchopleural fistula after sutured bronchial closure: incidence, risk factors, and management. *J Thorac Cardiovasc Surg*. 1996;112:1367-71.

18. Algar FJ, Alvarez A, Aranda JL, Salvatierra A, Baamonde C, Lopez-Pujol FJ. Prediction of early bronchopleural fistula after pneumonectomy: a multivariate analysis. *Ann Thorac Surg*. 2001;72:1662-7.
19. Deschamps C, Allen MS, Miller DL, Nichols FC 3rd, Pairolero PC. Management of postpneumonectomy empyema and bronchopleural fistula. *Semin Thorac Cardiovasc Surg*. 2001;13:13-9.
20. Klepetko W, Taghavi S, Pereszlenyi A, Birsan T, Groetzner J, Kupilik N, et al. Impact of different coverage techniques on incidence of postpneumonectomy stump fistula. *Eur J Cardiothorac Surg*. 1999;15:758-63.
21. Arnold PG, Pairolero PC. Intrathoracic muscle flaps. An account of their use in the management of 100 consecutive patients. *Ann Surg*. 1990;211:656-62.
22. Widmer MK, Krueger T, Lardinois D, Banic A, Ris HB. A comparative evaluation of intrathoracic latissimus dorsi and serratus anterior muscle transposition. *Eur J Cardiothorac Surg*. 2000;18:435-9.

Discussion

Dr Douglas Wood *(Seattle, Wash).* I congratulate Sherwood and colleagues for a well-analyzed series and a well-presented article. Pomerantz, Mitchell, and their group at the University of Colorado have long been leaders in the surgical care and the scientific evaluation of patients with complex mycobacterial infection. This article looks at the worst of the worst: completion pneumonectomy for infectious disease, a procedure fraught with technical difficulty and high morbidity and mortality. I must admit my deepest respect for the amount of work that Sherwood and colleagues have invested in caring for these patients and my admiration for their superb results. However, one cannot help but still note a formidable mortality of 31% and a BPF rate of 27%, even in the experienced hands of the Colorado team. I urge anyone, including myself, contemplating completion pneumonectomy in this patient group to consider referral to Colorado, or at least to follow the methodical and carefully outlined treatment plan presented in the published article. Dr Sherwood, I would like to ask you three questions.

First, are there any lessons to be learned when you analyze the patients who died or didn't have conversion of their sputum after surgery? Are there certain patterns of disease or certain organisms that we should consider as contraindications for surgery despite the poor prognosis with medical therapy?

Dr Sherwood. We previously published data that show that patients with mycobacteria other than tuberculosis or the environmental bacteria that most patients in the study had do probably face a higher mortality than patients who have *M tuberculosis.* In the same vein, these patients probably have a higher risk for BPF. These patients are extremely debilitated, and we are starting to realize—we have actually realized this for many years now but are starting to take more seriously—the debilitated nature of these patients and how malnourished they are. I think one of the things we can change is providing prolonged nutritional support for these patients before they go to surgery. Some of the patients that died had very low albumin levels. Some were very low weight and had very poor functional status.

Dr Wood. So we'll still operate on them, we'll just prepare them better.

Dr Sherwood. That's right.

Dr Wood. Second, it has long been known that right pneumonectomy, completion pneumonectomy, and infectious indication are all risk factors for BPF, and that is three strikes in this patient population I guess. With a nearly 50% incidence of right-sided BPF in your series, would you consider changing your technique and doing a hand-sewn closure of the stump rather than a stapled closure? I detect from the later phase of your series that you have changed your technique in terms of providing an omental soft-tissue flap rather than LDM. What about your bronchial stump closure in those cases?

Dr Sherwood. I don't think there are any data to support closure with a stapling device versus a hand-sewn suture technique in prevention of BPF. We have always used the stapling device, at least for the past 10 years, and we have had pretty good results in our other sets of patients. I think that the key to preventing BPF in these patients is using an omental flap. I think it provides excellent tissue coverage. It is pliable and incorporates into the interstices of the hilum better, and I think it also promotes angiogenesis and bronchial stump healing, so I think that is the main thing that we are going to change on the basis of the results of this study.

Dr Wood. Well, we may have a difference of opinion regarding the best way to close right-sided bronchial stumps. Finally, how do you decide between using omentum versus LDM? It sounds as though although you used LDM a lot early in your series, you have become progressively disillusioned with the LDM and are leaning more and more toward omentum. How do you differentiate when to use which?

Dr Sherwood. I think in this situation, given the fact that these patients have had a previous thoracotomy and most of them have some degree of division of the LDM, we always look at it after we harvest it and look at the viability of the distal portion of it. Even though it may look viable, there is probably some diminished blood flow and some fibrosis, and it probably doesn't provide what we think is good coverage and healing potential for the stump. I think that especially in this group of patients the use of omentum, which is technically not difficult but is more time consuming, will be the way we do these in the future.

Dr Peter Pairolero *(Rochester, Minn).* Clearly, this is a very difficult group of patients to manage, and each patient is an individual, with probably not a lot of similarity to the following or preceding patient. A point I want to make, though, is that almost all these patients have an infected thorax, and one of the difficulties of doing an omental operation is that you have to open up a sterile visceral cavity. That leads to the possibility of infection into the abdomen. In addition to that, you have to create some sort of hernia to get the omentum out of the belly. You either have to create an incisional hernia or you have to create a diaphragmatic hernia. I would like to offer another alternative, the serratus anterior muscle. In my experience, which is extensive, almost never is the serratus anterior muscle transected, and if it is transected, it's always transected in the lowest part. I have used the serratus anterior in preference to the LDM because the LDM is often not a good muscle, because it has been in a previous thoracotomy. But I would make the plea that the serratus anterior is better than the omentum for the reasons that I just enumerated.

Dr Sherwood. We used to use the serratus more often than we do now. One of the problems we have with these patients is that because they are so malnourished and debilitated, we have had problems with the wing scapula and that impairing the wound healing along the incision in that area. So we have kind of gotten away from using the serratus, but I agree that it is a handy muscle to use, and we may use it in certain situations.